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## MILITARY GEOLOGY

Chapter 9. MILITARY ROADS

Figures referred to herein are not reproduced but are evailable in the original document at the US Geological Survey.

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Terrain traversability and road networks are extremely important in the theatre of military operations. Mappleon was fond of saying, "The secret of war is the secret of communications," and "The strength of an ermy is measured by mass multiplied by speed."

In the section on fortifications we became acquainted with the means of fortifying a terrain with the aim of rendering it difficult of passage and converting it into an imaccessible area. In this chapter we shall be concerned with terrain traversability and the conditions for movement over it by various types of troops. In this matter the military geologist can aid greatly by giving the military experts specific data on the choice of the most suitable router for roads and on the construction materials available in the vicinity of the projected roads.

In Table 18 all factors are given which should be taken into consideration in the combat theater in a summary appraisal of the traversability of terrain (reliaf, ocils and grounds, rivers and lakes, marshes, woods, climate, etc.) The table also presents such poculiarities of reliaf as are not generally established in a morphological commination of the area — namely, isotropian or anistropy of the landscape, isot, the various degrees of difficulty of negotiating the area in predstermined directions.

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		Table 18	. Pactors in Ter	rain Traversability	7		
<u>Splief</u>	Spile and Graunds	Rivers and Lakes	Sergen a	Pereste	Climate	Characteristics	General Mature of Landscape
Commercing heights	Mechanical composition	Width, depth	Type of swamp Depth of solid ground	Species	Length of day and night	Lines of com- munication	Isotropies of area as affecting traversability
Slopes too steep for tanks	Cohesies	Speed of current	Thickness of peaty layer	Presence of unier- growth, density of crown	Air temperature, precipitation	Character of inhabited points	Anisotrophy of area as affecting traversa-bility
Slightly enamped slopes	Visco -ity, conditions of working	Behavior, thickness of ice	Euddiness Sponginess Stickiness	Average diam- eter of trunks	Fogs end cloudiness	Density of in- habited places	Surveyability of the area
Camouflage pos- sibilities ac- cording to re- lief features	Presence of sod	Presence of fords	Characteristics of vegetation	Average dis- tence bs- twoen trees	Wind	Hydraulic-engi- neering network	
Degree of vertical and horisontal		Conditions of approach		Amount of rub- bish in the			

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Roads have both strategical and tactical importance. In contemporary variars of maneuver, any highway or railroad may become a military objective. When railroad trunk lines, stations, bridges, etc., have been knocked out by cerial bonding, automobile and wagon roads take on an encreous importance. The laying of new routes, the restoration of destroyed roads, the improvement of old roads — those are the problems in the solution of which the military geologist must participate.

## Wilitery Communications

Lines of communication are the vital arteries which maintain an army. The experience of World War I showed that even in the period of positional warfare the army consumed a trainload of supplies per division deally, and in the period of active operations, up to 60 trains. To supply a division's combat activity for one day, an average of not less than 500-600 tons of ammunition is required, which constitutes one half of the general requirements. From October 1915 until 1, March 1917 on the Russian-German Front, 74,200 kilometers of dirt road were reconstructed, and 3,710 kilometers of trunk road and 318 k'lometers of new pavement were constructed. The American Army in its short stay on the front in 1918 constructed 275 kilometers of new pavement, and restored 3,500 kilometers of old pavement. The daily requirement of crushed stone ascunted to 3,000 tons.

In the Great Wer for the Fatherland, the scale of military road construction increased still more, and the destruction of lines of communication reached tremendous proportions.

The condition of roads must be taken into account for all movements and military operations. A plan of battle either offensive or defensive cannot be properly drawn up without an accounting of communications, i.e., without a consideration of the roads which link the front with the rear. There are engineer corps in all armies, whose basic tack is to make secure the movement and mansurering of troops. The geologist generally works as a part of the staff of the angineer corps or in contact with them.

military communications include the entire system of supply routes --railroads, mater transport, and automobile roads. A diagram of communications
in a combat some is presented in Figure 73, p 196.

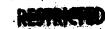
### Cross Country Routes of March

In the forward zone of a combat eros the revenent of troops is effected by specially constructed cross-country routes of march.

Cross-country routes of march are temporary roads of the simplest type, intended for movement of troop units with their materials and for other types of transports.

Ornes-country routes of march are constructed:

- 1. On the offensive, to secure the approach, through the defensive cone of the energy of infantry regiments, their regimental train, and artillery, and also for the transportation of troops and freight in the rear areas of regiments or divisions.
- 2. During preparations for the offensive, for tank units on their deplayment to their positions of readiness and during the passage of an echolon with a mission to develop a breakthrough from the intermediate position to the line of departure and further to the some of the breakthrough.
- In sevenents by reter transport, in order to provide for revenents in leading and unleading areas and the approaches to these areas.



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A great deal of work is required for the construction of cross-country lines of merch in mountainous theatres of operation. Laying them out in the spring, when roads are bad, is also fraught with great difficulties. The roads become particularly important in winter.

The rest importance of cross-country routes of march in the offensive was illustrated by the activity of the Red Army in 1942 in the liquidation of the so-celled Demyansk Base of Operations. A hundred kilometers of road, over which our infantry, artillery, and automotive transport moved, were laid in a marshy, wooded area, with insufficiently frozen ground, in deep, loose mov.

Cross-country routes of march often cross new land and afford the simplest passage through natural and artificial barriers (swamps, rivers, irrigation ditches, etc.). The projected course of a cross-country route of march must satisfy the following conditions: (1) correspond to the given direction and be as short as possible; (2) provide or at least facilitate essouflage; (3) avoid areas which facilitate the accumulation of poison gas or which pass through defiles (without jeopardising camouflage); (4) require the minimum outlay for their construction; (5) avoid intersection with other automobile and wagon roads; (6) proceed over the firmest possible ground (sandy, clayey soils, gravelly mixtures) so that the movement may proceed without road reinforcements; (7) secure the unhampered movement of the heaviest machines, motorised and mechanised forces, artillery, etc.

Infantry and tanks can move over almost any dry ground. Tanks can surmount grades of as much as 45 degrees. It is known from the experience of the Great Var for the Fatherland that tanks were often immobilised on difficult ground in rainy weather. Gross-country routes of march for horse-drawn artillery can be laid through sufficiently fire virgin soil or plowed land. The cross-country route of march for mochanised divisional or regimental artillery with tractors weighing from 5 to 10 tons can be laid out in marshy ground if the ground supports a pressure of no less than 0.5 kilograms per sq on. The basic elements of the cross-country routes of march are given in Table 19.

In the construction of cress-country routes of march one must take account of the engineering -- geological and hydrogeological conditions, the relief, and the presence of water obstacles and swampy areas.

In the autumn season of bad roads, the following rules must be observed:

- 1. To lay out the course along the watershed and places of fire ground (sands and sandy, clayey soils).
- 2. To evoid laying out the course through plowed fields, needows, or areas flooded by spring high water.
- 3. To avoid clayey ground and black loans. (In grounds having a moisture content of 20-25 percent, machines of ZIS and GAS models can move only in level areas or on slight grades; in sandy ground or sandy loam under the same conditions steeper grades can be negotiated.)

In wooded marshy places cross-country routes of march must be laid along paths and lance even if this mans lengthening the way between two selected points, and also through places of minimum density of trees.

laying out the course is marshy places entails considerable difficulty, especially for heavy automotive transport and artillery. Therefore, it is recommended that marshes be avoided if possible, or, if they must be crossed, that they be crossed at the marrowest place. In such a case the passages must be sufficiently wide, imamuch as certain types of marsh become impassable after the passage of a few mechanised white over the same open. To shall return to the question of traversability of essays later.



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Table 19. Basic Elements of Cross-Country Routes of March

		More the Deer	C wremewer or	01089-00mttl	monage of wat	wii	
_ Oursees of Route	Fint B	lein or Broken	Terrain	<u>Mo</u>	untainous Terr	<u>nin</u>	<u>Lenarke</u>
	Width of Passage (Noters)	Nax grade (%)	Mar Corve Mailine (Neters)	Width of Passage (Meters)	Nex grade (\$)	Max Gurve Endine (Neters)	
For movement of in- featry, cavelry and equipment	2.5-3	10-15	. 30	1-2.5	20	10	Fording depth for envelop, 1.2 meters; for lamestry, 1 meter
For artillery, mech- anised or horse-drawn	<b>5-3-</b> 5	12-15	30	2-5.3	15	20	Hoterised artillery om climb 18-195 elogge in exceptional cases firm dry ground.
For tanks	3-4	15-12	15	2•5 <b>-3•</b> 5	an-15	<b>15</b>	In medium dense woods of trees 25-50 on di eter, preliminary en gineering preparation is required.
For meterised units and automotive transport	3-5	3-10	. yo	3-3-5	12-15	15-25	For subsmotive transport fording depth is mini- mum compared to other means of locomotion -

BOTES: In forested, marshy, and mounte meters for stalled machines.

terrain a clearing must be made every 200-300

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Bearing in mind that in the rainy season water seriously damages roads, it is necessary when constructing roads is nountainous regions to employ all means to prevent landslips of earth and rooks, crumbling, and the erosion of roads.

## inter- and Asimal-Fransport Books

Notor- and animal-transport roads are classified according to surface:
(1) dirt and graval; (2) stone (chauses, cobblestons, etc.), (3) improved roads (black-top chauses, etc.), (4) superior roads (asphalt-concrete).

Table 20 gives a road classification in use in the USSR, showing the requirements of roads in varying relief landscapes.

Dirt roads are the prevailing type of road built in wartime. Improved roads and trunk-line roads are usually built in peccetime. Construction of dirt roads is reduced to the following operations: (1) elearing the road strip; (2) loosening nard ground; (3) longitudinal leveling; (4) lateral leveling of the roadbed; (5) grading the roadbed and packing the top layer; and (6) packing the road with a steam roller.

The section which follows deals with military reilroads. The pertinent data is summarized in Table 21.

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Table 20. Clammification of State Automobile Roads in the USSR and of Standard Basic Elements of Roads

Class of Road and Sature of Terrain	Clase I (Main Auto Boads)	Plain Plain	Class II Melief Broken	Kountain	Plain	Class III Relief Broken	<b>Kount</b> si s
Estimated speed in km/hour:							
a. Light motor vehicles in normal conditions	120	120	100	80	60	90	30
b. Light motor vahiales and trucks		<b>(=</b>	50	25	140	35	20
on slippery roads	න 1	65 2	70	Š	2	2	5
Fumber of Lanes	ИS	38	38	<b>7</b> 8		30 6	30 6 8
Width of total right of way in meters		70	70	~6	30 6	<b></b>	6
Width of traffic roadway in motors	3p	.!	11	8	10	10	8
Width of earth roadhed in meters	25	11	11		20		_
Redius of curves in \$1		****	760	200	1400	300	100
a. Ratio calculated	1500	1100	750	60	150	100	35
b. Minimum	500	400	250	ω	1,0	200	
Gradient limit in \$1	_	h	-	6	<b>14</b>	5	7
a. Naximus	3		?	7	5	í	ġ
b. In exceptional cases	4	5		,	,	•	
Distance of visibility in meters:				<b>ED</b>	90	80	140
s. On the level	160	550	150	50 25	90 45	<u> </u>	140
h in modile	150	110	75	e7	77		-

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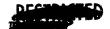
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# Table 21. Technical Corditions for Projection and Building Military Field Railroads

	ingta in appreviated form/	
Road Elements	Stem-Leconotive Traction	Diesel Locomotive or Boras Traction
Limitations of rise	Without discence limitation, 0.016. In especially dif- ficult conditions on a stretch of not over 100 meters, 0.050	For Diesel engine, asme as for stess. For horse traction, up to 0.020
Limitations of radius	50 meters; in stations, up to 40 meters	15 meters
Width of earth readbed	2.5 meters for sandy fills. 2.10 meters for branches built for a short time	For Diesel engine, same as for steem; for horse traction, 1.2 meters; in deep hollows, 3.80 meters is per- minsible
Thickness of ballast layer	0.10-0.20 meters	0.10-0.20 meters
Width of ballast layer on top	1.60 meters	For Diesel engine 1.60 maters For horse traction, 1.30 maters
Elevation of roadbed above level of highest water	0.30 meter (In case lines are con	0.30 meters structed for long duration)
Elevation of lower part of bridge girders above level of highest water	0.20 weter	0.20 meters
Distance between stations	10-16 meters; between railroad sidings, 5 km.	For Diesel engine, same as for ateam. For horse traction, 25 km; between sidings, 12,5 km
Greatest gradient at stations	0.002	0.010

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## Bridges and Water Crossings

Military bridges are divided into three classes: (1) bridges for attack, (2) bridges for convey, (3) stationary bridges.

Bridges for attack are used in forcing a river crossing. Included in this group are tank bridges brought up in preassembled form by special engineering tanks and constructed in less than 1 minute under enemy fire without the crew's leaving the tanks.

Eridges for convoy are intended for the crossing of the main forces and are constructed on floating and rigid supports. Light bridges can take a maximum load of 20-30 tons; heavy bridges, up to 50-70 tons.

Stationary bridges are constructed slong rear lines of communication on floating and rigid supports.

The most commonly used bridges constructed on dirt roads in a combat theatre are of the beam and brace type.

Military loads are classified as caterpillar loads (tanks, tractors) and wheeled loads (automobiles, artillary pieces). All standard bridges are divided in four classes on the basis of load capacity, as M1, M2, M3, M4, as shown in Table 22.

In computing the load capacity of bridges, the caterpillar-type loads are formed into a train. Thus, a first-class load (N 1) consists of a train made up either of caterpillar-type loads of 10 tons or of one wheeled type load with rear-axis pressure of 4 kg per sq cm.

Bridge materials are tested either with reference to a train of loads, an individual caterpillar load, or an axle, depending on which kind of load causes greater strain on the material which is being tested.

In combat areas, if a river forms a line of resistance, it is not always possible to construct a bridge; therefore troops are supplied with stream-crossing equipment (ferries, pneumatic floats, boats, etc.). In some cases disassembled bridges are used to see up bridges in important directions.

Troops often have to cross streams by fording, swimming, or, in winter, on ice. Tankettes can ford a stream no deeper than 0.05 meter; artillary and military trains, up to 0.70 mater; tanks (not amphibious), up to 0.90 meter; infantry, to 1 meter; and cavalry, up to 1.40 meters. Examples of heroic forcing of rivers under very unfavorable conditions can be cited from the Great War for the Fatherland, particularly the forcing of the Desma and the Duepr. Tank units crossed the Desma at the fording depth of nearly 2 meters, simply by plagging up the tanks apartures.

In making crossings on ice it is necessary to determine the ice's thickness and to bomere of boles and breaks caused by shells and bombs. When ice is 5 to 10 on thick, men spaced 2 meters apart can cross; with 10 to 15 centimeters of ice, howes and artil'ary can cross. With a thickness of 30 centimeters, any cannons and tanks can cross.

## Geological and Soil Research in Road Construction

Technical road research is usually divided into three phases: (1) reconnoisering, (2) detailed study, (3) reduction.

Reconncitering starts with a map study of the direction of a road. The line of the road course, the grades which one he climbel, bridges, nountain

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Table 22. Standard Militery Loads

Type		Catorpilla	r Loads			Wheeled Loads	\$
	General Weight (in Tone)	Longth of Caterpillar Tread (in Meters)	Width of Passage (in Meters)	Width of Caterpillar Tread (in Meters)	Pressure on Rear Axle (in Kg/Sq Cm)	Width of Passage (in Meters)	Width of Rim of Rear Wheel (In Neters)
# 1 # 2 # 3 # 4	10 40 70 45	3 4 5 5	2 2•25 2•5 2•5	0.25 0.25 0.50 0.50	6.7 10 15	1.5 1.5 1.7 1.7	0.2 0.4 0.4



passes, etc., are marked on topographical maps. Investigation of the terrain is carried out by means of preliminary markings or maps. Actual surveying involves a study of the relief, the physico-geological phenomena which might constitute a threat to the road (landelips, avalanches, cavernous terrain, etc.), and summps. Soil categories are studied from the point of view of road construction, and an appraisal is made of the conditions of travel on existing roads, etc. A number of alternative road courses must be considered in the study in order to have a basis for comparative evaluation.

The detailed study consists of spot surveys by instruments, in tracing lines on drafts with horizontals, in laying out the terrain, levelling the principal direction, etc.

Reduction work is carried out just before the construction of the road with the purpose of reducing the line, the introduction of necessary correctives in the road project, and preparing drawings and other documentation for the project.

## Selection of the Route of the Road

A road between given points should be as marly as possible a straight line. In peacetime, deviations may be justified by economic reasons; in wartime the basic requirements are speedy construction and assumance of troop movement. Furthermore, in projecting and constructing military roads, the demands of camouflage are imperative. Thus, the delection of the roads course determined by a complicated combination of reasons, and a straight line will not always be the most desirable direction of a military road. Furthermore, the location of road materials must be considered as a factor in shottening the construction time.

The following factors determine the correctness of choice of the 1/2d's course:

- 1. The minimum amount of earth work and smellest number of bridges required.
  - 2. The firmness and solidity of the soils and strata
  - 3. Noarness of location of construction materials.
- 4. Suitability of the terrain for the camouflagin; of the road and trop movements

## Study of Soils and Grounds

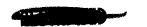
in handling problems of road construction, the most convenient classification of soils is that of N. M. Sibirtsev, which divides all soils into three classes: sonal, intrasonal and azonal.

Class I, somel soils: (1) tundra soils; (2) podsol soils; (3) transitional soils (interest and steppe) (4) black-earth soils (steppe soils); (5) chestnut-brown and brown soils, grayish soils (soils of dry and semiarid steppes); (6) laterites (subtropical soils)

Class II, intrusonal soils: (1) saline soils ("solonete") soil and marshy soils /solodi/; (2) "solonetak" soils ("solonetak") and breakish-warshy /solonetakovo-bolotnyye/ soils; (3) marshy soils (peat, peaty-gley, meadow and cony gleys); (4) gleyey-podsolic soils (semi-marshy); (5) dark-colored soils (black-earth type soils); (6) human-carbonated soils.

Class III, asonal soils: (1) Alluwial soils (river); (2) eroded and washed soils; (3) coarse stony, gravelly, and pebbly soils; (4) pine-forest sandy soils;





(5) surface outcropping and exposure of soil-forming strata.

In the distribution of soils it is necessary to take into account certain uniformities:

- 1. The law of horizontal soil zones (formulated by N. M. Sibirtsev). Soils occur in zones (or strips) which alternate from north to south.
- 2. The law of vertical soil zones (proposed by V. V. Dokuchayev). Given two slopes the bases of which have similar geological characteristics, the succession of soil types along each slope will also be si ilar.
- 3. The law of soil microzones (Academician Afanas yev). In small relicf depressions soils are disposed in the form of miniature vertical zones.

All three of these laws can be corbined in one general law of analogous torographical scries of soils (a vertical zones corresponds to each horizontal zone.)

- 4. The law of reversal of soil zones ( ... Filatov and I. . Krasheninnikov). The disposition of mountainous regions and ridges and the direction of slopes bring about a transposition and displacement of soil zones both vertically and along the slopes, depending upon orientation with relation to the points of the compass.
- 5. The law of soil regions (L. I. Frasolov). Is a consequence of local physical geographic conditions, soil zones are divided into more or less extended regions often far removed fro each other.

Field examination of the soils is carried out with the aid of small prospecting pits and pit-holes. The prospecting pits are 0.80 meter by 1.70 meters in cross section and are generally sume to a de th of 1.5 to 2 meters. One of the sides is located facing the sun, which permits a careful study of all the morphological characteristics of the soll and a separation of genetic levels and sublevels. Specimens are gathered at the same time. Control pits (half-pits) are dug less deeply - to a depth of one meter (cross section 0.65 meter by 1.30 meters).

Records of the examination are kept according to a definite form. (Table 23)

In addition to the granulometric properties of the soil it is also necessary to take into account the electrochemical processes taking place in connection with carillar the nomena. These phenomena differ in soils of dissimilar origin, even though the granulometric composition of these soils may be similar.

## Traversability of Swamps and the Construction of Roads Through Wamps

Midespread marshy areas and swamps are to be found in regions of excessive mainture, mainly in the forest some of temperate climate geographically connected with the funternary glacial region.

Swamps occupy a vast part of the territory of the USSR. They are found in the southernmost steppe regions, where swampy bottomlands, called "[lavni, " have developed in the lower parts of the Onerr, Don, and Tuban Rivers. Inundations occur even in semiarid regions where usually dry rivers bring down in springtime a great volume of water which accumulates in the low-places. This is the way salt lake-swarps, of the type found in Kazakhstan are formed.

The following data is needed for military road construction through swamps:

1. Designation of the swamy and geographical location, distance from inhabited places or other orientation points.



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E O	Type of ground Hydraulic of Subsoil wat	und~soil en onditions ( er level w	d name of surface dr	basement roc ainage, surc ed	eptibility	(Second		Thickness according to the accepted scale		New formations, admixtures,	Evaluation of construc- tion proper- ties of ground
4. 5.	Type of ground Hydraulic of Subsoil wat Settling	und~soil en onditions ( er level w	d name of surface dr	basement roc ainage, surc	eptibility	to fleeding					3 3 4 5 6 7 7
4. 5.	Type of ground Hydraulic of Subsoil wat Settling	und~soil en onditions ( er level w	d name of surface dr	basement roc ainage, surc	eptibility	to flooding	s. etc.)				\$
4. 5.	Type of ground Hydraulic of Subsoil wat	und~soil en onditions ( er level w	d name of surface dr	basement roc ainage, surc	eptibility	to flooding	s. etc.)				
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Table 24. Granulometric Classification of Soils of the Section of Animal-Traction and Pawed Roads of the MKYD, USSR

Boils

## Contents of components in \$ by weight

·	Sandy (2.00 ~ 0.05 mm)	Dusty (0.05 - 0.005 mm)	Clayer (less than 0.005 mm)
Sandy Sandy-dusty	Particles 2.00-0.25 mm	Less than 15% 15-50% Less than in sandy	Ress than 3% Ress than 3% 3-12%
Sandy-loam	over 50%	Less than in sandy	3-12\$
Fine sandy-loam	Particles 2.00-0.25 mm less than 50%		
Dusty Clavey	Greater than dusty Greater then dusty	Greater than in sandy	Less than 12% 12-18-% 18-25%
Heavy clayey Dusty clayey Clayey	vionet time during	Greater than sandy	12-25% over 25%

- BOTE: 1. For construction purposes sands are divided into four types:

  a. Coarse sand -- with more than 50% of particles from 2-1 mm

  b. Medium sand -- with more than 50% of particles larger than 0.5 mm

  c. Small sand -- with less than 50% of particles larger than 0.5 mm

  Small send -- with more than 50% of particles larger than .25 mm

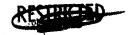
  d. Very small sand -- with more than 50% of particles smaller than .25 mm

  2. Soils composed of over 10% of particles larger than 2 mm belong in the gravelly or stony type.

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- 2. Geomorphological characteristics of the landscape of the also, neculiarities of the meso- and micro relief, the presence of hillocks and stagment pools. It is necessary to indicate the origin of the relief element with which the swamp is connected (whether it is the product of placentian or the activity of existing rivers, etc.)
- S. Vegetation: kind of trees, approximate diameter, etc., grassy cover-
- 4. Conditions of water supply of the awamp (direction of the nurface runoff and the average degree of slope of the awamp's ourface)
  - 5. Presence of drainage networks
- 6. Thickness and nature of the peat, its carrying nower and the ground of the swamp's base

In choosing a crossing through a swarm one should be guided by the following considerations:

- 1. The swamp should be crossed at its marrow at point.
- 2. The route should cross the stamp at its challengest point (usually this is the same as the narrowest point).
  - 3. The roads should be laid where the swamp bottom lies horizont lly.
- 4. The height of the embendments must be determined in such a way that the rim of the finished readbed will rise above the bottom of the embankment no less than 0.5 meter above the capillary rise level of the water in the ground of the embankment.

## Betablishment of a Drainage System

The establishment of a proper system of drainage, upon which the regular functioning of the road depends, is of basic importance.

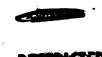
Leter: 1 ditches, cut as trapszoids or triangles, here to lever the level of subscil vator or to drain off water flowing from the surface of the readbed or the slopes of excevations. Ditches may be dispensed with only when the read is located on an embandment (over 0.5 meter high) of sandy or gravelly ground affording good drainage. When contending with fast flowing vator, the ditches should be reinforced. Their denth depends upon the nature of the soil and the width of the earth readbed. (See Taule 35, p 229).

Special drainage systems are constructed to protect the base from being soaked by subsoil waters, especially in ground which has high capillarity or a marked tendency to form chasms. The depth of the drainage system depends upon the level of the water table, the capillary peculicrities of the seil and the depth of freezing.

The requirements of drainage of a military road will then depend upon (1) the condition of the weather and the weather forecast for the set period of use of the road; (2) the relief features of the area; (3) the level of the water table; and (4) the soil.

## Causes of Deterioration of Roads

To insure the continuous use of roads they must be regularly inspected and remaired. All dirt roads except send roads deteriorate in wat weather; clay roads may become impassable with deep mui. Even paved roads are subject to complete destruction by use and from the weather. The following recommendations are made for maintaining roads in good shape: (1) use of the whole width of the road by vehicles, not just one track; (2) setting apart a separate route for



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motor transport; (3) inclusion within motorized columns of special machines which level off ruts and holes in the road; (4) spraying dirt roads in dry weather with a solution of calcium chloride (20 percent concentration) in the amount of 0.8 to 1.1 kg per sq meter. Calcium chloride, being hygroscopic, causes hardening of the ground and minimizes dust formation.

# Appreciant of the Elements Affecting Travereability in the Theater of Hilitary Operations

An entries of the traversability of a region and of the conditions affecting road construction should be made in the light of past and future combat operations in a given area of the theater of military operations. It is necessary also to take into consideration the high degree of mechanization of graced and ongineering troops.

In vertice, the work of the geologist in road-surve, crews acquires particular importance. The geologist must often give detailed analyzed an penriosys and make accurate and hold decisions in the field, immediately and without proparation. This enhances still more the importance of geological work in highest matters during a period of military operations.

The goolo, ist concerned with problems of traversability and with the exploration of cross-country routes of march, roude, crossings, etc., must not be confined until the corrow limits of the specialty, since goological factors are only consets of traversability and not always the most important assocts. The goological notice of notices and hydrogeology are of no large importance. The goological convice of military industry and the notice of the relation of the relation and the one hand, be book on a theorem, and, on the other, must utilize the latest methods of studying the physical and not mainly characteristics of soils. The goologist must be acquainted with not) ode of highway construction and ith measures for improving the quality of reacheds (stabilization of soils) since reach must be built even under the most adverse conditions and on unstable fround.

The geologist should exhibit great initiative in searching for local material for ground reinforcement. The charts of road traversability should include such factors as geomorphological conditions (for example a slope steeper than 30 degrees, ground soil, deposits of construction materials for the paving and improvement of roads, nighways, vegetation, swamps, salt marshes, rivers (fords)—in a word, everything that is necessary for an accurate appraisal of the traversability of the region.

In the various landscape zones it is necessary to give a clear account of the relative importance of isolated elements affecting traversability, as follows:

## 1. Hornhology and Geology

These elements are of importance or incivally in mountainous countries. Every mountainous country has its own morphologic and tectonic structure which determines the conditions of traversability.

The treat of encirclement possesses great importance in mountain warfore and is a problem for defense. Therefore, it is important here to make an
approximate of passes and narrow defiles which hamber maneuverability. Terrain
conditions in the mountains conform to specific vertical zoning, which must be
determined with the maximum possible core, since the boundaries between zones are
not established merely by horizontal and absolute marks, but show many variations
depending on the asymmetry of slopes, their exposure, the asimuth direction of a
mountain range, and the whole range of artificial elements produced by the hand
of man (the felling of woods, fields, plowed land).

It is necessary to distinguish within the boundaries of the vertical



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landscape zones geomorphologic complexes, whose reculiarities are identified by geologic formations. Here it is importent to point out not only the composition of the rock, but also its stratification. Alpinists well know how much easier it is to scale granite cliffs than shale.

## 2. Ground-Soil Conditions

These conditions are of predominant importance in steppe, semiarid, and arid zones. An appraisal of the traversability of ground soils involves the consideration of:

- a. Horizontal and vertical zonation of soils
- b. Natural cohesion of soils and grounds
- c. Extent to which bad roads are produced during wet weather
- d. Degree of soil and ground stability during dry weather with regard to formation of dust
- e. Conditions of soils and grounds typical of given areas (drynoss, wetness, time and curation of the senson of bad reads, etc).

### 3. Climatic Factors

The study of climatic factors is carried out by the hydrometeorological service. Although these factors do not constitute a basic objective for geological investigation it is necessary to take them into account for a complete appraisal of the traversability of a region. Problems of saturated ground, dust, the appearance of snow cover, chasms -- all these are linked with hydrometeorological conditions.

Snow cover is of prime importance among meteorological factors affecting the traversability of mountainous regions. The most significant phases of the location of the snow line must be plotted on the chart of the elements of traversability. In northern regions the beginning and duration of the frost period is of great importance. Marshes and rivers in these regions may serve as good communication routes during frost regions. Consequently, it is important to record the time of freezing and thaving of the rivers, the thickness of the ice, etc. (These data can be recorded in the form of isolines on charts.)

Particular attention should be paid to weather forecasts. The success of operations frequently depends on weather forecasts. In particular, the settling of fogs has great importance for the success of sudden operations. Fogs covering the rivers morning and evening and remaining for prolonged periods on lakes effectively mask operations on water from aerial observation and thus aid orossings.

## 4. Vegetation

This element must be considered together with morphological and groundsoil conditions. In forested regions vegetation is one of the main factors affecting traversability. It is necessary to distinguish:

- a. Swamp vegetation
- b. Woods and scrub
- c. Grassy vegetation (meadow, steppe, and desert)
- d. Caltivated vegutation (gardens, parks, crops, vineyaris, corn fields, etc.).

Plant cover developed on areas of land influences road characteristics both positively and negatively. In the first case, grassy vegetation forces a sturdy



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sed facilitating traversability. In the second, the presence of hillocks in swampy meadows hampers movement.

### 5. Bodies of Water

Rivers, lakes, and summe are important elements affecting traversability. Tithout a careful study of these objects, their banks and their genetic peculiarities, it is impossible for the geologist to offer advice in the selection of crossings and bridges. Sloping banks permit transport to cross at almost any place on a river. Steep, abrupt, and rocky banks complicate passage across mater barriers. Swamp areas on the banks of a river hamper the novement of transport.

## 6. Means of Communication

A network of roads of various types is necessary for the facilitation of traversability of territory in the theater of operations. The geologist participates in the selection of the course of the road and in its construction. In a number of instances he may be called upon to appraise the traversability of the territory held by the enemy. Without consideration of routes of communication such an appraisal would be incomplete, and this obliges the geologist to be sufficiently familiar with all types of roads and with the elements affecting their construction. Furthermore, construction assists in establishing cartain peculiarities of the natural conditions of the landscape (size of a valley, the width of rivers, the steepness of slopes, etc.)

At the same time, it is necessary to know the methods for the most rapid restoration of roads. Basic types of obstructions or obstacles which may be encountered on roads in war time are:

- a. Mined and contaminated fields
- b. Sections with landslides, obstructions, barriers, fissures, crators, ite.
  - c. Sections with various types of wire obstructions
  - d. Ground stream with broken glass, thorns, and spikes
  - e. Sections with water obstacles and artificial glaze

Tracing of road boundaries is a preliminary step in the work of restoration of a road. The geologist may be consulted in planning dotours of damaged sections of roads and also in scarching for local deposits of handy mineral construction materials for repairing roads, filling in creters from projectiles and bombs, and reclaiming swamped sections of roads, etc.

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